XMM-Newton Observations of two high redshift quasars: RX J1028–0844 and BR 0351–1034 [1]

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ABSTRACT

We report the results of XMM-Newton observations of two high redshift quasars, one radio-loud, RX J1028.6–0844 (z=4.276) and one radio-quiet, BR 0351–1034 (z=4.351). We find that the evidence for strong excess absorption towards RX J1028–0844 is marginal at best, contrary to previous claims. The superior sensitivity and broader, softer energy range of XMM-Newton (0.2-10 keV) allows better determination of spectral parameters than much deeper ASCA observations (0.8-7 keV). Our XMM-Newton observations call into question several other ASCA results of strong absorption towards high redshift radio-loud quasars. RX J1028.6–0844 occupies the same parameter space in broad band spectral properties as the low redshift BL Lac objects, showing no obvious evolution with redshift. The radio-quiet quasar BR 0351–1024 became fainter between ROSAT and XMM observations by a factor of at least 5, but with the present data we cannot determine whether there is an associated spectral change. These observations do not support previous claims of weaker X-ray emission from high redshift radio-quiet quasars. The soft X-ray spectral slope required to reconstruct the ROSAT PSPC hardness ratio of BR 0351–1034 is about $\alpha_{\rm X}$=3.5, the steepest X-ray slope ever observed in a high redshift quasar, and similar to that of low redshift Narrow Line Seyfert 1 galaxies.

Subject headings: galaxies: active - quasars:general - quasars: individual (RX J1028–0844, BR0351–1034)

1. Introduction

High redshift quasars are interesting not only for their record setting quality but also because they can tell us about the formation of quasars and about conditions in the first few percent of the age of the Universe. They allow us to study the evolution of a quasar's central engine e.g. (Vignali et al. 2001), the star formation in the early Universe (e.g. Dietrich et al. (2002)), and the intergalactic medium between the high redshift quasar and us (e.g. Péroux et al. (2001)). Prior to ROSAT (Trümper 1982) only one quasar with z> 4.0 was detected in X-rays, GB 1508+5714 (z=4.30, Mathur & Elvis (1995)). Only one high redshift quasar was discovered during the ROSAT All-Sky Survey (RASS, Voges et al. (1999)), RX J1028.6–0844 (Zickgraf et al. 1997). The first X-ray selected high redshift quasar was RX J1759.4+6632 (z=4.320, Henry et al. (1994)) found in a deep ROSAT Position Sensitive Proportional Counter (PSPC, Pfeffermann et al. (1987)) observation. Other sources were detected in X-rays, but selected in other wavelength bands, typically by their radio emission, e.g. GB 1428+4217 (z=4.72, Boller et al. (2000)) or at optical wavelengths (e.g. Q0000–263, z=4.111, Bechtold et

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al. (1994)). Thanks to the Sloan Digital Sky Survey (SDSS, York et al. (2000)) the number of high redshift quasars, even to redshifts z>6, has increased dramatically and several of them have been detected in X-rays. (e.g. Mathur et al. (2002); Brandt et al. (2002); Vignali et al. (2003a))[2].

While detection of these $z > 4$ quasars in X-rays has opened up a new field of research, the results are conflicting. For example, Brinkmann et al. (1997a) and Bechtold et al. (2001) find that high redshift quasars are more X-ray quiet and have flatter X-ray spectra than the low z quasars, in contradiction to the Mathur et al. (2002) results. Vignali et al. (2003a) also advocated that high redshift quasars are more X-ray weak, but from a larger sample Vignali et al. (2003b) concluded that the trend is with luminosity rather than redshift. One main reason behind these contradictory results is that they have all been based on short, snapshot observations. The resulting total counts, of order of a few tens, are generally too few to permit spectral analysis. As a result, derived quantities such as $\alpha_{\rm ox}$[3] have a strong dependence on the underlying assumptions of spectral shape and absorbing column density. To understand high redshift quasars, and to compare them to their low redshift cousins, we have initiated a program to obtain X-ray spectra of high redshift quasars using XMM-Newton. The sample consists of both radio-loud and radio-quiet quasars to probe differential evolution between the two classes, if any. Here we present results of the AO 1 observations of a radio-loud quasar RX J1028–0844 and a radio-quiet quasar BR 0351−1034.

The high redshift quasar RX J1028.6–0844 (RASS position: α_{2000}=10h 28m 38.9s; $\delta_{2000} = -08°44'29''$; z=4.276) was identified by Zickgraf et al. (1997) in an identification program of northern X-ray sources (Appenzeller et al. 1998) detected during the RASS. Its PSPC count rate during the RASS was 0.035±0.011 cts s^{-1} which transfers to a rest-frame 2-10 keV luminosity $L_{2-10{\rm keV}} = 6.4 \times 10^{46}$ ergs s^{-1} which makes it one of the most X-ray luminous sources in the Universe (Zickgraf et al. 1997). RX J1028.6–0844 is associated with a close by radio source PKS B1026–084 with flux of 220 mJy at 5 GHz in the Parkes radio survey (Otrupcek & Wright 1991). From its extreme luminosities at all wavelengths and its radio loudness RX J1028.6–084 is considered a BL Lac object (Yuan et al. 2000). In a long 67 hour observation by ASCA (Tanaka et al. 1994), Yuan et al. (2000) found evidence for very high neutral absorption at the rest-frame of RX J1028.6–0844. Assuming solar abundances an absorption column of $2\times 10^{23}{\rm cm}^{-2}$ was found. However, it was not clear from the ASCA data whether this absorption is associated with the quasar or if it is related to a damped Lyα absorber at z=3.42 (Péroux et al. 2001).

The high redshift radio quiet quasar BR 0351–1034 (α_{2000}=03h 53m 46.9s, $\delta_{2000} = -10° 25' 19.0''$, z=4.351) was discovered by the APM high-redshift quasar survey by Irwin et al. (1991). Storrie-Lombardi et al. (1996a) reported that BR0351–1034 was one of the most unusual sources of their survey of high-redshift APM Quasars with intervening absorption systems. They found saturated CIV absorption and a large number of absorption lines associated with damped Lyman α absorption systems at z=3.633, 4.098, and 4.351. The source was first detected in X-rays by ROSAT in a 9.1 ks pointed PSPC observation with 54±13 counts (Kaspi et al. 2000).

In this paper we present the results of the XMM-Newton (Jansen et al. 2001) observations of these two quasars. The short (5 ks) observation of RX J1028.6–0844 was planned before the long ASCA observation. The supreme sensitivity of the EPIC PN detector (Strüder et al. 2001) at soft X-rays and recent calibration efforts, allow measurements down to 0.2 keV (or even less, Haberl et al. (2003)), putting better constrains on the intrinsic absorption of the source than from previous X-ray missions. Our 26 ks observation of BR 0351–1034 was severely affected by the high background radiation. As a result, the spectral quality of the source was significantly compromised, and so the spectral parameters are not well constrained.

The paper is organized as follows: in § 2 we describe the observations and data reduction, in § 3 we present the results of the X-ray observation which will be discussed in § 4.

Throughout the paper spectral indeces are en-

[2]A complete list of z>4 quasars with X-ray detections is given at www.astro.psu.edu/users/niel/papers/highz-xray-detected.dat

[3]The X-ray loudness is defined by (Tananbaum et al. 1979) as $\alpha_{\rm ox}$=–0.384 $\log(f_{2{\rm keV}}/f_{2500\AA})$.

ergy spectral indeces with $F_\nu \propto \nu^{-\alpha}$. Luminosities are calculated assuming a ΛCDM cosmology with $\Omega_{\rm M}$=0.3, Ω_Λ=0.7, and a Hubble constant of H_0 =75 km s^{-1}Mpc^{-1}, using the formulae given to derive the luminosity distances given by Hogg (1999). All errors are 1σ unless stated otherwise.

2. Observations and Data Analysis

2.1. Radio-loud quasar RX J1028.6–0844

RX J1028.6–0844 was observed by XMM-Newton on May 15th, 2002 for a total of 5 ks with the EPIC PN (Strüder et al. 2001) and 7.3 ks with the EPIC MOS (Turner et al. 2001) detectors using thin filters. A high background flare was present during a short time of the observation. We excluded this time by creating a good time interval (GTI) file accepting only times when the background count rate of photons with energies > 10 keV was less than 10 cts s^{-1}. Only the EPIC PN observation was significantly affected by the flare. The GTI screening of the PN data results in a total observing time of 4350 s. Source photons in the EPIC PN were collected in a circle with a radius of 35$''$ and the background photons in a circle of a radius of 60$''$ close by. The source photons in the MOS detectors were selected in a circle with a radius of 31.25$''$ and the background from an annulus of 35$''$ inner radius and 75$''$ outer radius. We selected single and double events (PATTERN $\leq$ 4) for the PN and single, double, triple and quadruple events (PATTERN$\leq$ 12) for the MOS, for which the detectors are calibrated.

In addition to the XMM-Newton data of RX J1028.6–0844 we also retrieved the ASCA data from observation of November 25th, 1999 (seq-id: 77011000; Yuan et al. (2000)) from the ASCA data archive at Goddard Space Flight Center in order to fit our XMM-Newton data together with the ASCA data. Due to the decrease in efficiency below 1 keV of the ASCA Solid-state Imaging Spectrometers (SIS) after late 1994 (see ASCA webpage heasarc.gsfc.nasa.gov/docs/asca/watchout.html) we considered only photons with $E > 0.8$ keV for our analysis.

2.2. Radio-quiet quasar BR 0351–1034

BR 0351–1034 was observed by XMM-Newton on 2002-08-23 for a total of 26.0 ks with the EPIC PN and 27.7 ks with the EPIC MOS detectors using thin filters. Due to a high background radiation during the last half of the observation, these data were unusable. The data were screened to create a GTI file with background count rate of photons with energies > 10 keV to be less than 10 cts s^{-1}. This screening results in total observing times of 15.8 ks and 19.5 with the PN and MOS detectors, respectively.

Source counts were collected in a circle with a radius of 15$''$ and the background from a near by circular region with a radius of 30$''$. Because of its small number of counts (Sect. 3.2.1) only the EPIC PN data with single and double events (PATTERN$\leq$4) were used for the spectral analysis. Because of the faintness of the source, the results may be affected by the choice of the background region. We determined background from another near by region as well, and found the results with the two different backgrounds to be consistent with one another within errors.

The source was observed in a pointed ROSAT PSPC observation on 1992-01-27 (Obs-ID rp700531; Kaspi et al. (2000)) for a total of 9.4 ks. We retrieved the data from the ROSAT Archive at MPE Garching and reanalyzed them. The source photons were collected in a circle with R=75$''$. Since the source is faint, again we selected two background regions, one in a circle with R=150$''$ near the source and a second one in an annulus around the source with an inner radius R=100$''$ and an outer radius R=200$''$. Again, we found that the choice of the background did not affect our results.

For both the sources, the XMM-Newton data were reduced using the XMM-Newton Science Analysis Software (XMMSAS) version 5.3.3 and the X-ray spectra were analyzed using XSPEC 11.2.0. The spectra were grouped by GRPPHA 3.0.0 in bins of at least 20 counts per bin. For both sources, the Ancillary Response Matrix and the Detector Response Matrix were created by the XMMSAS tasks *arfgen* and *rmfgen*. The ASCA spectral data of RX J1028.6–0844 were selected by XSELECT, grouped by GRPPHA like the XMM-Newton data, and analyzed by XSPEC. The ROSAT data of BR 0351–1034 were analyzed using the Extended X-ray Scientific Analysis System (EXSAS, Zimmermann et al. (1998)) version 01APR. For the count-rate conversions between different X-ray missions, PIMMS 3.2 was used.

3. Results

3.1. RX J1028.6–0844

3.1.1. The XMM-Newton observation

The mean count rates measured for the EPIC PN, MOS1 and MOS2 were 0.416±0.010 cts s^{-1}, 0.115±0.004 cts s^{-1}, and 0.094±0.005 cts s^{-1}, respectively. On the short time scale of the observation (the 5 ks EPIC PN observation converts to ≈ 1ks in the object's rest-frame) we could not detect any significant variability. We converted the EPIC PN count rate into ROSAT PSPC and ASCA SIS count rates by using PIMMS and could not detect any significant changes in the count rate on long time scales either. None of the observations so far have shown any significant variability in this source. Yuan et al. (2000) discussed the temporal analysis of their 67 h ASCA observation and also found no significant variability.

Table 1 summarizes the results of a simple power law fit with 'cold' absorption of neutral elements at z=0 to the XMM-Newton data of RX J1028.6–0844. The fits to all instruments separately agree within the errors, except for the MOS-1 which shows a slightly higher absorption column than the other detectors. This latter is driven by one data point at about 0.7 keV (see Figure 1), so the discrepancy does not appear to be significant. The X-ray slope is about α_X=0.3. This is in good agreement with what has been found for other high redshift radio-loud quasars (e.g. Ferrero & Brinkmann (2003)). When data from all the three XMM-Newton detectors are fitted together with absorption fixed at the Galactic value ($N_H = 4.59 \times 10^{20}\mathrm{cm}^{-2}$; Dickey & Lockman (1990)), the fit is good with $\chi^2 = 169$ for 160 degrees of freedom (DOF, see Table 1 and Figure 2). If the absorbing column density is left as a free parameter, the fit yields $N_H = 7 \pm 1 \times 10^{20}\mathrm{cm}^{-2}$ and χ^2=174.6 (161 DOF). Thus the best fit N_H is consistent with the Galactic value, within errors, and the spectra do not show any compelling evidence of excess absorption.

3.1.2. Comparison with ASCA spectra

The above result contradicts earlier ASCA results, reported by Yuan et al. (2000), who found strong excess absorption towards the source. To quantify the difference and to verify the ASCA results we fitted the XMM-Newton and ASCA data with a power law plus galactic absorption (fixed to the galactic value) and intrinsic redshifted neutral absorption at the redshift of the quasar. We used the XSPEC model *zvfeabs* for the redshifted intrinsic absorption. The metal abundance $Z/Z_\odot$ was set to unity (solar abundance). The results of these fits are given in Table 2. Here the ASCA SIS detectors show a very high intrinsic column density of $N_{\mathrm{H,intr}} = 15.2 \pm 14.0 \times 10^{22}$ cm^{-2} which confirms the results found by Yuan et al. (2000). However, fits to the PN data result in much lower column densities, as discussed above. Higher column densities are obtained with MOS detectors, which do not have well calibrated response below 0.5 keV and even higher column densities are found with ASCA SIS which has no response below 0.8 keV. Thus the inferred high column density appears to be a direct result of lack of low energy response of these detectors.

To better understand the difference between XMM-Newton and ASCA results, we performed the following additional tests. At first, we fitted the data by fixing the intrinsic column density and X-ray slopes to the ones found by ASCA ($N_{\mathrm{H,intr}} = 21.1 \times 10^{22}\mathrm{cm}^{-2}$, α_X=0.72, Yuan et al. (2000)). In the 0.2-1.0 keV range we can clearly see strong deviations at energies below 0.8 keV (Figure 3). However, at energies above 0.8 keV the data agree very well with the values found from the fits to the ASCA data. Using the XMM-Newton and ASCA data only in the ASCA SIS 0.8-6.5 keV energy range results in much higher column densities than when the whole detector energy ranges are used (Table 2). The data in the 0.8-6.5 energy range of the XMM-Newton detectors are indeed more or less consistent with the parameters found by ASCA. Clearly, the lack of low energy response of ASCA SIS gives incorrect results, and the superior sensitivity of XMM-Newton in the soft energy band down to 0.2 keV allows us to make accurate measurement of the absorbing column density.

Figure 1 displays the result of a powerlaw fit with galactic and intrinsic absorption simultaneously to the XMM-Newton PN and MOS-1 & MOS-2 and ASCA SIS-0 & SIS-1 data (Table 2). All the data including the ASCA SIS data are well-fitted with an X-ray spectral slope α_X=0.3 and an intrinsic absorption column $N_{\mathrm{H,intr}} \approx 10^{22}$

cm^{-2} with solar metal abundance, an order of magnitude lower than the column density based on ASCA data alone.

To summarize, the XMM-Newton spectra do not show strong evidence for excess absorption towards RX J1028-0844. If there is excess absorption at all, and if it is at the redshift of the quasar, then it is an order of magnitude lower than that inferred from ASCA data,

3.1.3. Broad band Properties

RX J1028.6–0844 is associated with a nearby radio source PKS B1026–084 within the RASS error circle (Zickgraf et al. 1997) and references therein; radio position: α_{2000}=10h 28m 39.0s, $\delta_{2000} = -08°44'36''$). The X-ray source position is better determined with the XMM-Newton observation to be α_{2000}=10h 28m 38.9s, $\delta_{2000} = -08°44'39.2''$ for the PN camera. Thus the difference in radio and X-ray source positions is only $3.2''$, well within the XMM-Newton absolute pointing accuracy of $15''$, and also within the boresight error of $3'' - 4''$ (Ehle et al. 2003), making the identification secure.

The radio flux at 5 GHz given in the Parkes Catalogue (Otrupcek & Wright 1991) is 220 mJy. This corresponds to a k-corrected luminosity density of log $l_{4.85\rm GHz}$=34.6 erg s^{-1} Hz^{-1}. The radio-to-optical slope $\alpha_{\rm ro}$[4] was calculated from the k-corrected luminosity densities to be $\alpha_{\rm ro} = 0.48$. This converts to a radio loudness R[5] ≈180 which makes this source a radio-loud object as per the definition of Kellermann et al. (1989); radio-quiet, -loud division at R=10. The radio spectral slope is $\alpha_r = -0.3$ (Zickgraf et al. 1997), making this a flat spectrum radio-loud object, and the high luminosity suggests a possible BL Lac identification (Yuan et al. 2000). The slope of the X-ray power-law of the source is also flat ($\alpha_{\rm X}$≈0.3; Table 1), similar to other radio-loud sources (e.g (Elvis el al. 1986; Brinkmann et al. 1997b)).

From the R magnitude R=17.1 mag given at the position of RX J1028–0844 in the US Naval Observatory Catalogue A2.0 we estimated the rest frame flux density at 2500Å to log$f_{2500\text{Å}}$ = −26.4 ergs s^{-1} cm^{-2} Hz^{-1} assuming an UV spectral slope $\alpha_{\rm UV}$=0.8 as given in Vignali et al. (2001, 2003a) and a correction for de-reddening with $\frac{N_{\rm H}}{E_{\rm B-V}} = 4.93\ 10^{21} {\rm cm}^{-2}\ {\rm mag}^{-1}$ (Diplas & Savage 1994). The unabsorbed rest-frame 2keV flux density is log $f_{\rm 2keV} = -29.0$ ergs s^{-1} cm^{-2} Hz^{-1}, which results in an X-ray loudness of $\alpha_{\rm ox}$=1.08. This is different from the value $\alpha_{\rm ox}$=0.79 given in Vignali et al. (2001), but comparable to the $\alpha_{\rm ox}$ values of other high redshift BL Lac sources. The difference in the two values of $\alpha_{\rm ox}$ is due to the different values of R magnitude used as inputs. We obtained the R magnitude from the USNO A2.0 catalogue while Vignali et al. (2001) used an R magnitude from the literature, probably R=18.9 given in Zickgraf et al. (1997).

3.2. BR 0351–1034

3.2.1. The XMM-Newton Observation

The mean count rates are (6.26±2.39) 10^{-3} cts s^{-1} for the EPIC PN, and (2.93±0.48) 10^{-3} cts s^{-1} and (2.29±0.48) 10^{-3} cts s^{-1} for the EPIC MOS 1 and 2, respectively. This results in total numbers of background subtracted source counts of 100 for the PN and 58 and 45 for the MOS 1 and 2. The number of counts in the PN detector are enough, while those in MOS 1 and MOS 2 are not, to perform a simple spectral analysis. So we focus only on the PN in the following for spectral analysis.

Table 3 summarizes the results of spectral fits to the EPIC PN data of BR 0351–1034. The first fit was a simple powerlaw with 'cold' absorption of neutral elements in our Galaxy ($N_{\rm H,gal} = 4.08 \times 10^{20} {\rm cm}^{-2}$; Dickey & Lockman (1990)). The fit is good with $\chi^2 = 2.3$ for 7 DOF. Figure 4 displays this fit to the PN data of BR 0351–1034. If absorption is allowed to be a free parameter, the best fit column density is consistent with the Galactic column density within errors. However, given the low data quality, we cannot rule out intrinsic absorption of the order of a few times $10^{22}$$cm^{-2}$(Table 3, Figure 5). Motivated by the ROSAT result (see below), we also tried a fit with a broken powerlaw model with a soft X-ray spectral slope $\alpha_{\rm X,soft}$=3.5 as derived from the ROSAT data. The fit is good, implying consistency with the ROSAT data but the data quality is not high enough to provide a conclusive

[4]The radio-to-optical spectral slope is defined by (Zamorani et al. 1981) as $\alpha_{\rm ro} = -0.185 \log(l_{2500\text{Å}}/l_{4.85\ \rm GHz})$

[5]Radio loudness R = $f_{5\ \rm GHz}/f_{4400\text{Å}}$

result on the presence of a broken power-law.

3.2.2. *Comparison with ROSAT*

The count rate during the ROSAT PSPC observation was determined using both background regions in the PSPC; both rates agree within the errors with a rate of $3.63\pm1.34\,10^{-3}$cts s^{-1}. Based on the PSPC count rate, we expect a PN count rate CR=0.039 cts s^{-1} for a simple powerlaw model with Galactic absorption (see Table 3), but measured only about 1/6th of it. Clearly the source varied in intensity between the ROSAT and XMM-Newton observations.

The number of photons from the pointed ROSAT PSPC observation was 34.2±12.7, not sufficient for a spectral analysis. However, it is possible to derive a hardness ratio[6] in order to see whether the spectrum is soft or hard. The measured hardness ratio is HR=–0.24±0.57 and implies a steep soft X-ray spectrum. In order to get a hardness ratio HR=–0.24 for the PSPC data, a powerlaw model with galactic absorption requires a spectral slope $\alpha_{\rm X}$=3.5. This is a very steep X-ray slope and would be even steeper if the source is also intrinsically absorbed. Thus it is unlikely that there was excess absorption towards the source during the time of the ROSAT observation. In order to search for spectral variability we used the models derived from the XMM data (Table 3), folded those by the response matrix of the ROSAT PSPC, and calculated the hardness ratios in the PSPC energy band. For a powerlaw model with $\alpha_{\rm X}$=0.75 and $N_{\rm H}$=4.08× 10^{20}cm^{-2} we derived a HR=+0.51 and for $\alpha_{\rm X}$=1.19 and $N_{\rm H}$=13.59× 10^{20}cm^{-2}a HR=+0.93. Although this is a rough estimate, it suggests that the source has become harder in the XMM observation compared to the ROSAT PSPC observation 10 years before (in the observed frame).

Note that a broken power-law model with $\alpha_{\rm X,soft}$=3.5 and only Galactic absorption (Table 3) fits the PN data well, allowing consistency with the ROSAT data. On the other hand, the model with excess absorption brings the expected count rate down by a factor of 3.5, compared to the observed decrease by a factor of 6. This means that a variable absorber can be responsible for most of the flux variability observed in BR 0351–1034, but the X-ray source still has to be intrinsically variable by a factor of about 2.

[6] HR=(H-S)/(H+S) with S counts in the 0.1-0.4 keV range and H=0.5-2.0 keV

3.2.3. *Spectral Energy Distribution*

From the UV spectrum given in Storrie-Lombardi et al. (1996b) we derived the optical flux density at 2500Å rest-frame. The rest-frame flux density at 2 keV was calculated based on the simple powerlaw fit to the EPIC PN data (Table 3). This results in an optical to X-ray spectral slope $\alpha_{\rm ox}$=1.51. The 0.2-2.0 and 2.0-10 keV rest-frame X-ray luminosities are log $L_{\rm 0.2-2.0keV}$=45.5 [ergs s^{-1}] and log $L_{\rm 2.0-10.0keV}$=46.4 [erg s^{-1}]. This converts to a bolometric luminosity of log $L_{\rm bol}$ ≈ 46.7 ergs s^{-1} using the relation[7] given in Grupe (2003) derived for a low-redshifted soft X-ray selected AGN sample.

4. Discussion

4.1. The radio-loud QSO RX J1028.6–0844

As discussed above, RX J1028.6–0844 is a flat spectrum radio-loud object. The high radio and X-ray luminosities suggests that the emission is beamed and the source is possibly a BL Lac object, in which we are viewing the source down the radio jet axis. The flat X-ray spectral slope of this source is also consistent with this interpretation. Also, the values of $\alpha_{\rm ox}$ and $\alpha_{\rm ro}$ of RX J1028–0844 when placed in the $\alpha_{\rm ox}$ vs. $\alpha_{\rm ro}$ diagrams of Laurent-Muehleisen et al. (1999) and Beckmann et al. (2003) argue for the BL Lac nature of this source. However, the presence of a Lyα emission line in the identification spectrum of RX J1028–0844 (Zickgraf et al. 1997) and the lack of significant X-ray variability in the source argue against a blazar classification. Even though a lack of variability is unusual for a BL Lac object, it is not unknown (e.g. Tagliaferri et al. (2003)).

Based on ASCA data, RX J1028.6–0844 was believed to have strong intrinsic absorption (§ 3.1.2). Another high redshift blazar, PMN J0525–3344

[7] *log* $L_{\rm bol}$ = 0.44 + 1.02 × *log* $L_{\rm 0.2-2.0\ keV}$. Note, that this relation is determined for a Friedman cosmology with H_0=75 km s^{-1}Mpc^{-1} and q_0=0.0 and luminosities given in units of Watts.

also shows extremely strong X-ray absorption, again in ASCA spectrum, more than a million times greater than the neutral hydrogen or dust column density implied by its optical spectrum (Fabian et al. 2001). Faced with the difficulty of explaining this observation, Fabian et al. (2001) invoke highly ionized, and dust destroyed, absorbing gas close to the nucleus, similar to the warm absorber commonly seen in Seyfert galaxies. Another z> 4 blazar, GB 1428+4217, was also claimed to have strong intrinsic absorption based on ASCA data (Fabian et al. 1998). Now our XMM-Newton observations question these findings, because at least in the case of RX J1028.6–0844 we find the ASCA results to be spurious. As shown in Figure 2 and Table 1 the data are consistent with only Galactic absorption. If present at all, the column density of the intrinsic absorber is more than a factor of 10 smaller than that previously suggested from ASCA observations by Yuan et al. (2000). The superior sensitivity of the XMM EPIC PN detector down to energies of 0.2 keV (Strüder et al. 2001) allows us to put much better constrains to the models than with data of previous X-ray missions.

Our results are in accord with those of Ferrero & Brinkmann (2003) and Elvis et al. (2000), who also found that the evidence for excess absorption in PKS 2149–306 to be marginal based on XMM-Newton and BeppoSAX data respectively, in contrast to previous ASCA results (Cappi et al. 1997). It is also interesting to note that ROSAT observations of GB 1428+4217, which are similarly sensitive to low energies, also imply an order of magnitude lower column density than the ASCA results (Boller et al. 2000). The only radio-loud high redshift quasar in which XMM observations confirmed the ASCA claims of excess absorption is PKS 2126–158 (Ferrero & Brinkmann 2003). Note, however, that PKS 2126–158 is a giga-hertz peak spectrum (GPS) source (de Vries et al. 1997; Stanghellini et al. 1998). GPS sources are thought to be young radio-loud quasars and/or in denser environments (O'Dea et al. 1991). The excess absorption observed towards PKS 2126–158 may then be in its immediate environment.

However, the claims of excess absorption towards high redshift radio-loud quasars are not all from ASCA observations. Elvis et al. (1994) and Cappi et al. (1997) obtained a similar result based on ROSAT observations. It should be noted though that the ROSAT results are not very robust, with excess absorption in candidate radio-loud sources with low-energy cutoffs being consistent with zero within 2σ (Fiore et al. 1998). Better quality spectra with XMM-Newton will certainly help resolve this issue, and the effort is already underway.

The excess absorption towards RX J1028.6–0844 is weak, if present at all, and as a result we can neither constrain its metalicity nor redshift. Yuan et al. (2000) have discussed in detail the possibility of intervening material as the absorber and suggested a galaxy about $7''$ away from the position of RX J1028.6–0844 found in the image obtained by Zickgraf et al. (1997) as a possible site. Péroux et al. (2001) found a weak damped Lyα system at z=3.42 and z=4.05 and estimated the column density to be log $N_{HI} \gtrsim 20.1$ [cm^{-2}]. We fitted the XMM-Newton PN and MOS data simultaneously to a redshifted absorber with z=3.42 and solar abundance resulting in an absorption column N_H=0.93× 10^{22}cm^{-2}. If the abundance is sub-solar, similar to that found in other damped Lyα systems (Bechtold et al. 2001), the effective total column density would be even higher. The z=3.42 damped system is thus an unlikely site for the X-ray absorption, but a lower redshift damped system is a possibility. It is also quite possible that the excess absorption, if present, is local to our own Galaxy. The observed Galactic column density is averaged over 1 square degree based on the HI maps of Dickey & Lockman (1990) and it is quite possible that the actual column density is somewhat higher either due to a neutral or molecular cloud.

The major objective of our observing program was to compare the properties of high redshift quasars to their low redshift cousins. For this reason, we placed RX J1028.6–0844 on the $\alpha_{\rm ro}$ vs. $\alpha_{\rm ox}$ plot for complete samples of low redshift radio-loud quasars (Fabian et al. (1999); please note that Fabian et al. (1999) define their spectral energy slopes at 5500 Å and 1keV instead of conventional 2500 Å and 2keV). We find our source to lie right in the region occupied by the BL Lac objects. Comparison with a similar plot by Siebert et al. (1998), where BL Lacs occupy the regions of $0.6<\alpha_{\rm ox}<1.6$ and $0.25<\alpha_{\rm ro}<0.75$, also shows

that RX J1028.6–0844 does not occupy any conspicuously different region. Thus the present observation does not show any evolution of broad band properties with redshift. The $\alpha_{\rm ox}$ value of RX J1028.6–0844 occupies lower end of the distribution of radio-loud quasars by Wilkes et al. (1994), implying larger X-ray luminosity, if any, compared to the lower redshift quasars.

4.2. The radio-quiet quasar BR0351–1034

BR 0351–1034 is variable by a factor of about 6 on a timescale of 1.75 years (in the rest-frame). While variabilities in X-rays with factors of 3 or 4 on timescales of days are quite common among AGN (e.g. Leighly (1999); Grupe et al. (2001)), evidence of strong variability among high redshift quasars is sparse. With the present spectral quality, we cannot distinguish among following scenarios: (1) flux of BR 0351–1034 decreased from the time of ROSAT observation to the time of XMM-Newton observations, but the spectrum did not change; (2) flux decreased in part due to excess absorption during the XMM-Newton observation; and (3) flux decreased and the spectrum hardened. All the three types of variations have been observed in low redshift AGN: e.g. in IRAS1334+24 the flux changed between the ROSAT All Sky Survey and the pointed observation by over a factor of two, but the spectral shape did not change (Grupe et al. 2001); in NGC 3516 spectral change due to change in absorber column density has been reported (Mathur et al. 1997) and in the Narrow-Line Seyfert 1 galaxy RX J0134.2–4258 (Grupe et al. 2000) spectral change is observed with change in flux.

The UV/optical - X-ray broad-band spectral slope of BR0351–1024 is $\alpha_{\rm ox}$=1.51. This is as expected for a radio-quiet quasar with optical luminosity density of log $l_{\rm o}$=31.7 ergs s^{-1} Hz^{-1} (Yuan et al. (1998), see their figure 11). Thus, our observations do not support earlier claims that high redshift radio-quiet quasars are weaker in X-rays compared to lower-z quasars (Brinkmann et al. (1997a) and Ferrero & Brinkmann (2003)).

The most interesting, but tentative result is that BR0351–1024 has a very steep soft X-ray slope. In order to reconstruct the ROSAT PSPC hardness ratio HR=–0.24 a steep soft X-ray slope $\alpha_{\rm X}$=3.5 is needed and the XMM-Newton spectrum is also consistent with such a steep slope (Sect. 3.2.1). While such steep X-ray spectra have been observed in a number of Narrow-Line Seyfert 1 galaxies (e.g. Boller et al. (1996); Grupe et al. (1998); Grupe et al. (2001)), only one other high redshift quasar (SDSS J1044-0125 at z=5.8) with possible steep X-ray spectrum is known (Mathur (2001); note that the 0.1–0.4 keV range in the observed soft band corresponds to rest frame 0.53–2.1 keV in the rest frame of BR0351–1034, similar to the ROSAT band). It is commonly believed that the steep soft X-ray spectra in NLS1s are the result of close to Eddington accretion (e.g. Pounds et al. (1995)). Is BR0351–1034 also in a very high accretion state? Given the bolometric luminosity of log $L_{\rm bol}$ $\approx$ 46.7 [ergs s^{-1}] Eddington accretion rate implies a black hole mass of about a few times $10^8 M_\odot$. According to accretion-disk corona models (e.g. Kuraszkiewicz et al. (2000)), it is difficult to generate such steep X-ray spectra around such massive black holes. Or is the soft X-ray emission a result of Compton thick outflows associated with Eddington or super-Eddington sources (King & Pounds 2003)? These are intriguing questions, which we can answer only after confirming the suggestive evidence presented here. If true, the steepness of the soft X-ray slope in BR0351–1034 supports the proposal of Mathur (2000) that high redshift quasars and NLS1s are similar objects, perhaps at an early stage of their evolution (Grupe (1996); Grupe et al. (1999) and Mathur (2000)). This hypothesis has been recently supported by the findings of Yuan & Wills (2003) who showed that high redshift quasars are at the same extreme end of the Boroson & Green (1992) 'Eigenvector 1', as the NLS1s.

5. Summary & Conclusion

We have studied the XMM-Newton data of the high redshift blazar RX J1028.6–0844 and a radio-quiet quasar BR0351–1034. We found that the evidence of excess absorption towards RX J1028.6–0844 is weak at best. If present, the column density of the redshifted absorber is more than 20 times smaller than what has been previously suggested from ASCA data. Location of the absorber is unconstrained, and it may well be in our Galaxy. A longer, 40 ks XMM-Newton observation in AO2 (PI W. Yuan) will be valuable to confirm the excess absorption if any and to get better constrains on the location and metallicity of the absorber.

Our observations of BR0351–1034 were compromised due to high radiation background, but the present data do not support claims of X-ray weakness in high redshift radio quiet quasars. Similarly, the X-ray properties of RX J1028.6–0844 do not appear to be significantly different from low redshift BL Lac objects. Clearly, we cannot draw any definite conclusions about quasar evolution from just two observations, and we will publish the results from our entire sample as and when all the observations are made. There is a tantalizing evidence of steep soft X-ray slope in this source, supporting the hypothesis of Mathur (2000) about the evolution of AGN. We also have more XMM-Newton observations of radio-quiet quasars approved in cycle 2 and 3, including a longer observation of BR0351–1034, which will help confirm and extend the results presented here.

We would like to thank Matthias Dietrich for the discussions on abundances in high redshift quasars, Weimin Yuan for intensive discussions on the ASCA observation of RX J1028–0844, Michael Freyberg for discussions on calibration issues, David Weinberg for providing a program to determine the luminosity distances of the sources, and the anonymous referee for a fast referee's report and useful suggestions on the manuscript. This research has made use of the NASA/IPAC Extra-galactic Database (NED) which is operated by the Jet Propulsion Laboratory, Caltech, under contract with the National Aeronautics and Space Administration, and data from the US Naval Observatory catalogue A2.0. The ROSAT project is supported by the Bundesministerium für Bildung und Forschung (BMBF/DLR) and the Max-Planck-Society. This work was supported in part by NASA grant NAG5-9937.

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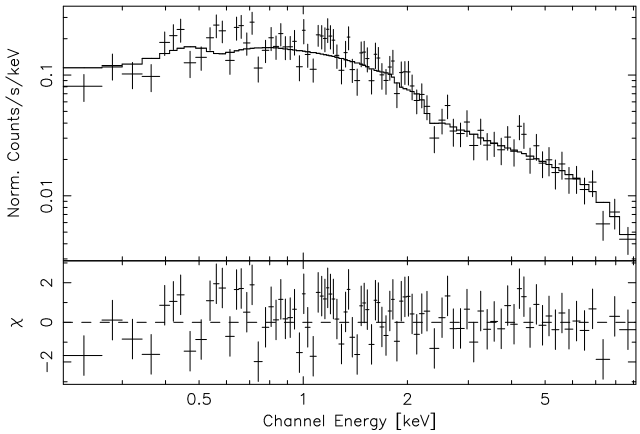


Fig. 2.— Powerlaw model with Galactic absorption fitted to the PN data of RX J1028.6–0844 ($\alpha_{\rm X}$=0.233, $N_{\rm H} = 4.59 \times 10^{20}{\rm cm}^{-2}$; Table 1).

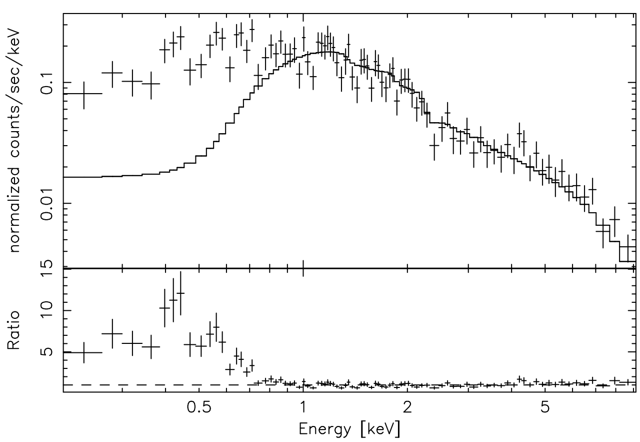


Fig. 3.— Power-law plus neutral Galactic and redshifted intrinsic absorption using the values from the fit to the ASCA data of RX J1028–0844 ((Yuan et al. 2000), $N_{\rm H,intr} = 21.1 \times 10^{22}{\rm cm}^{-2}$, $\alpha_{\rm X}$=0.72). The figure clearly shows that the XMM data agree with the ASCA model for energies > 1keV but deviate significantly in the soft X-ray band.

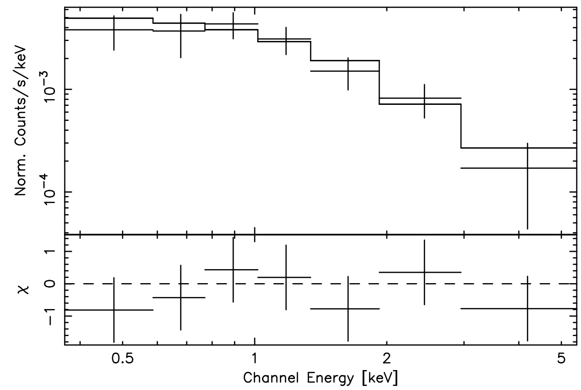


Fig. 4.— Power-law model with neutral Galactic absorption fitted to the EPIC PN data of BR 0351–1034 ($\alpha_{\rm X}$=0.75, $N_{\rm H} = 4.08 \times 10^{20}{\rm cm}^{-2}$; Table 3). .

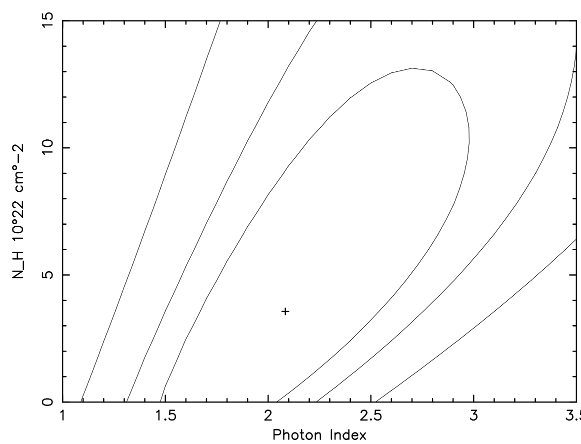
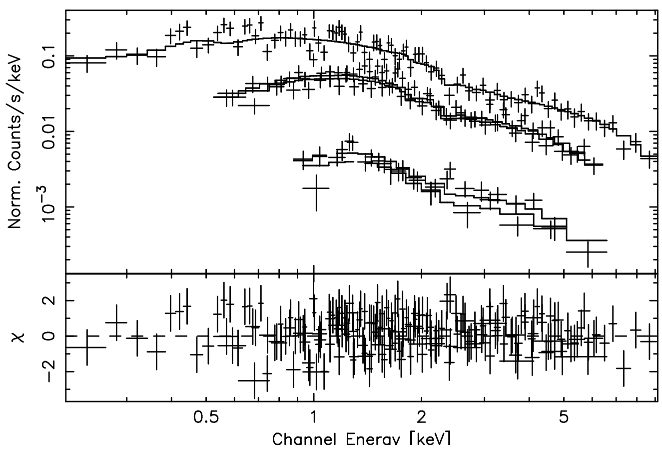


Fig. 5.— Contour plot with the 68%, 90% and 99% confidence levels of the Column density of the intrinsic absorber vs. the Photon index of a powerlaw model with Galactic and intrinsic neutral absorption fit to the EPIC PN data of BR 0351–1034 (Table 3).



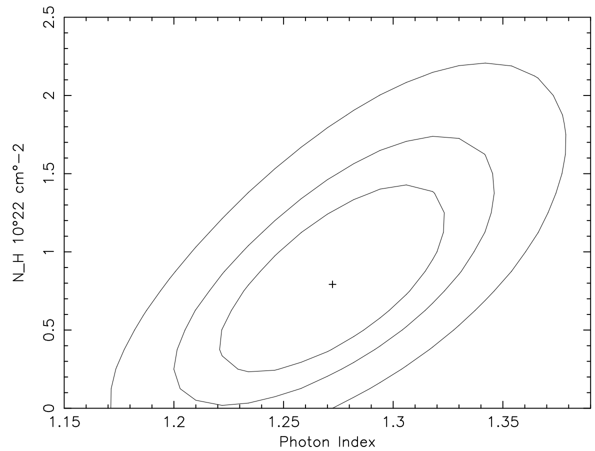


Fig. 1.— Power-law fit with neutral galactic absorption (fixed to galactic value) and intrinsic absorption with metal abundance = solar to the EPIC PN, MOS-1 and 2, and ASCA SIS0 and SIS 1 data of RX J1028.6–0844 (α_X=0.272, $N_{\rm H,intr} = 0.79 \times 10^{22}{\rm cm}^{-2}$, Table 2). The left panel shows the fits to the spectra of the EPIC PN (top) MOS (middle), and ASCA SIS (bottom) detectors. The right panel displays the 68%, 90% and 99% confidence levels of the Column density of the intrinsic absorber vs. the Photon index (Photon index Γ=α_X+1; Tab 2).

Table 1

Spectral Fit parameters of RX J1028.6–0844 for a power-law model with neutral absorption at z=0.

Detector	$N_{\rm H}$ $10^{22}{\rm cm}^{-2}$	α_X	χ^2 (DOF)
PN[1]	0.0665±0.0128	0.307±0.054	91.8 (84)
	0.0459 (fixed)	0.233±0.032	95.2 (85)
MOS-1[2]	0.1653±0.0486	0.424±0.110	40.3 (35)
	0.0459 (fixed)	0.194±0.595	47.0 (36)
MOS-2[2]	0.0883±0.0451	0.314±0.112	31.5 (37)
	0.0459 (fixed)	0.225±0.060	32.4 (38)
MOS-1[2]& MOS-2[2]	0.1251±0.0332	0.368±0.079	73.0 (74)
	0.0459 (fixed)	0.209±0.042	79.4 (75)
ASCA SIS-0[3]& SIS-1[4]	0.0611±0.1465	0.416±0.207	26.3 (28)
	0.0459 (fixed)	0.397±0.100	26.5 (29)
PN[1]+ MOS-1[2]& MOS-2[2]	0.0712±0.0119	0.298±0.042	169.0 (160)
	0.0459 (fixed)	0.225±0.025	174.6 (161)
PN[1]+ ASCA SIS-0[3]& SIS-1[4]	0.0715±0.0122	0.331±0.047	119.0 (113)
	0.0459 (fixed)	0.249±0.031	124.5 (114)
PN[1]+ MOS-1[2]& MOS-2[2]+ ASCA SIS-0[3]& SIS-1[4]	0.0725±0.0114	0.304±0.040	211.8 (189)
	0.0459 (fixed)	0.229±0.025	206.0 (190)

[1]Energy range 0.2-10 keV

[2]Energy range 0.5-7.5 keV

[3]Energy range 0.8-7.0 keV

[4]Energy range 0.8-6.5 keV

Table 2

Spectral Fit parameters of RX J1028.6–0844 for a power-law model with galactic neutral absorption at z=0 and redshifted intrinsic absorption. The galactic absorption is fixed to $N_{\mathrm{H,gal}} = 4.59\ 10^{20}$ cm^{-2} ((Dickey & Lockman 1990)).

Detector	$N_{\mathrm{H,intr}}$ 10^{22}cm^{-2}	α_{X}	χ^2 (DOF)
PN[1]	0.781±0.447	0.300±0.048	91.0 (84)
MOS-1[2]	5.57±2.68	0.378±0.105	41.7 (35)
MOS-2[2]	2.17±2.38	0.302±0.203	31.4 (37)
MOS-1[2]& MOS-2[2]	4.07±1.83	0.347±0.075	78.2 (75)
ASCA SIS-0[3]& SIS-1[4]	17.90±14.16	0.748±0.321	24.8 (28)
PN[1]+ MOS-1[2]& MOS-2[3]	0.87±0.41	0.277±0.036	169.7 (160)
PN[1]+ MOS-1[2]& MOS-2[2]+ ASCA SIS-0[3]& SIS-1[4]	0.89±0.43	0.280±0.035	200.7 (189)

[1]Energy range 0.2-10 keV

[2]Energy range 0.5-7.5 keV

[3]Energy range 0.8-7.0 keV

[4]Energy range 0.8-6.5 keV

Table 3

Spectral Fit parameters to the EPIC PN data of BR 0351–1034

XSPEC Model	$N_{\mathrm{H,gal}}$ 10^{20}cm^{-2}	$N_{\mathrm{H,intr}}$ 10^{22}cm^{-2}	$\alpha_{\mathrm{X,soft}}$	$\alpha_{\mathrm{X,hard}}$	χ^2 (DOF)
wa powerlaw[1]	13.59±12.79	—	—	1.19±0.66	1.2 (4)
	4.08 (fixed)	—	—	0.75±0.27	2.4 (5)
wa zwa po[2]	4.08 (fixed)	3.58±4.45	—	1.08±0.48	1.1 (4)
wa bknpo[3]	4.08 (fixed)	—	3.50 (fixed)	0.73±0.28	3.0 (4)
	12.70±11.81	—	3.50 (fixed)	1.13±0.62	1.2 (3)

[1]galactic absorption and powerlaw model

[2]galactic absorption, redshifted neutral absorption at z=4.351 and powerlaw

[3]galactic absorption and broken powerlaw with observed break energy E_{break}=0.45±0.18 keV.